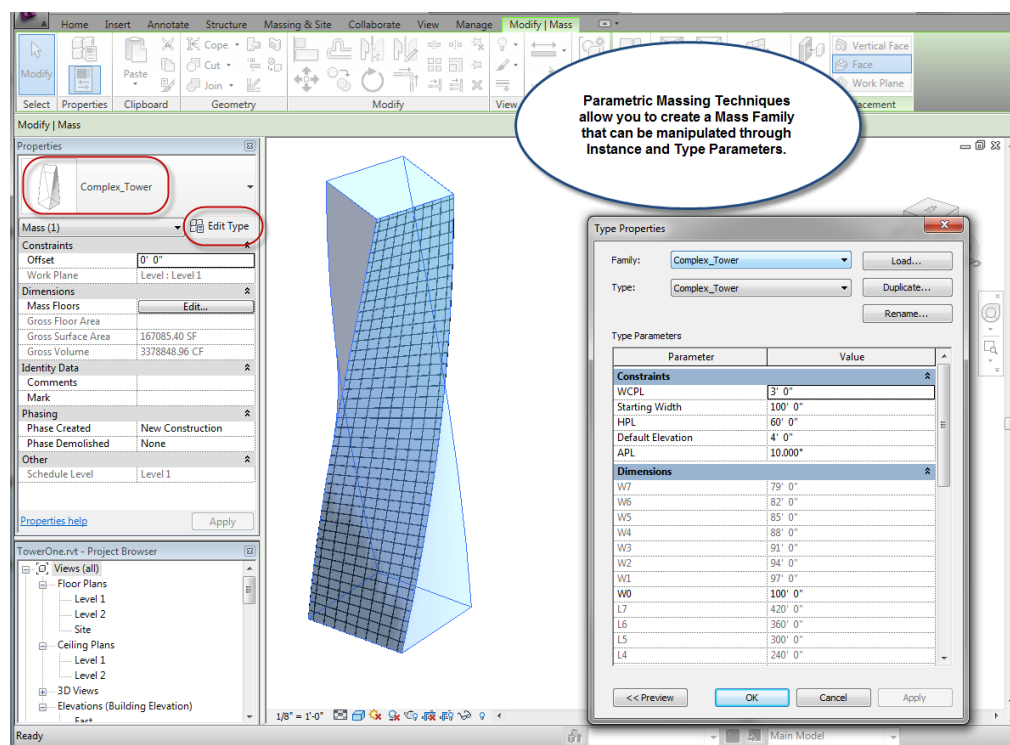


AGENDA:

1. Dimensioning Forms and Labeled Dimensions
2. Working with Parameters and Formulas

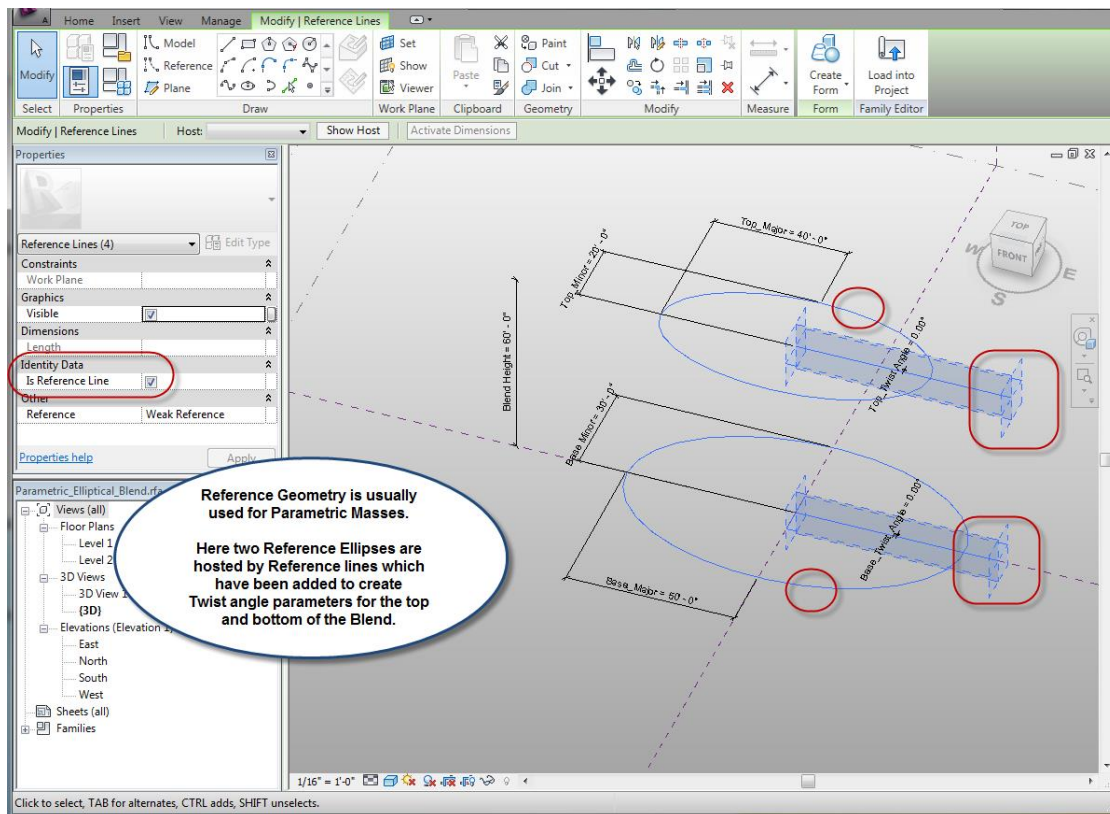
1. Dimensioning Forms and Labeled Dimensions

There are two basic workflows one can follow when generating a conceptual mass. The first option is to create an intuitive mass which will usually be developed from model lines, often as an In-Place family. Forms based on model lines are unconstrained and lend themselves more easily to direct manipulation. It is also possible to create an Intuitive mass in the Family Editor but the final shape is modified directly by pushing and pulling on faces, edges, profiles, etc.



The second approach one can use in developing a conceptual mass is to use parameters and formulas to mathematically define and drive the size and shape of the final form. This approach is best accomplished in the Family Editor where it is easier to view and work with reference planes and levels and also to create labeled dimensions and other parameters.

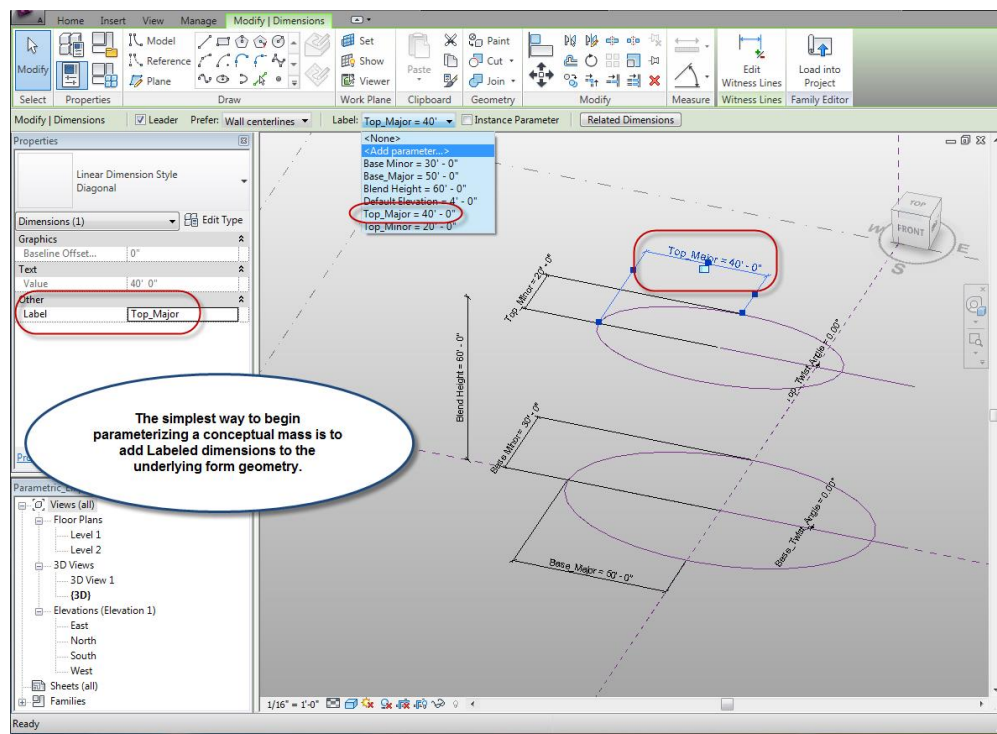
The geometry for a parametric mass is usually developed from reference lines instead of model lines. The reference based forms cannot be intuitively modified as easily as unconstrained forms created from model lines, but they usually respond more reliably to being parameterized.



Reference Lines are especially useful for controlling angle parameters such as the twist or rotation angle for a blend form. Add a Reference line and align one of its endpoints to the origin of the two main reference planes. The other end can be rotated in any direction and an angular dimension can be added and then labeled to control the rotation angle.

Reference lines can be hosted by Levels or Reference Planes. The reference lines themselves define four reference planes and one of these planes can be set as the host for the further reference geometry which will be created to define the form. In this way, a hierarchical relationship is developed. Moving or rotating the reference line will also move or rotate any forms hosted on any of the reference lines. Moving the level or plane on which the reference line is hosted, will move the reference line and in turn, any of its hosted forms.

The dimensions for a form can be set a number of ways. In the Intuitive massing workflow, forms are manipulated and resized directly using 3D controls on faces and edges, or by editing temporary dimension values. In the Family Editor, it is also possible to add permanent dimensions to conceptual masses and then label these dimensions to create Length (Linear) and Angular constraints.



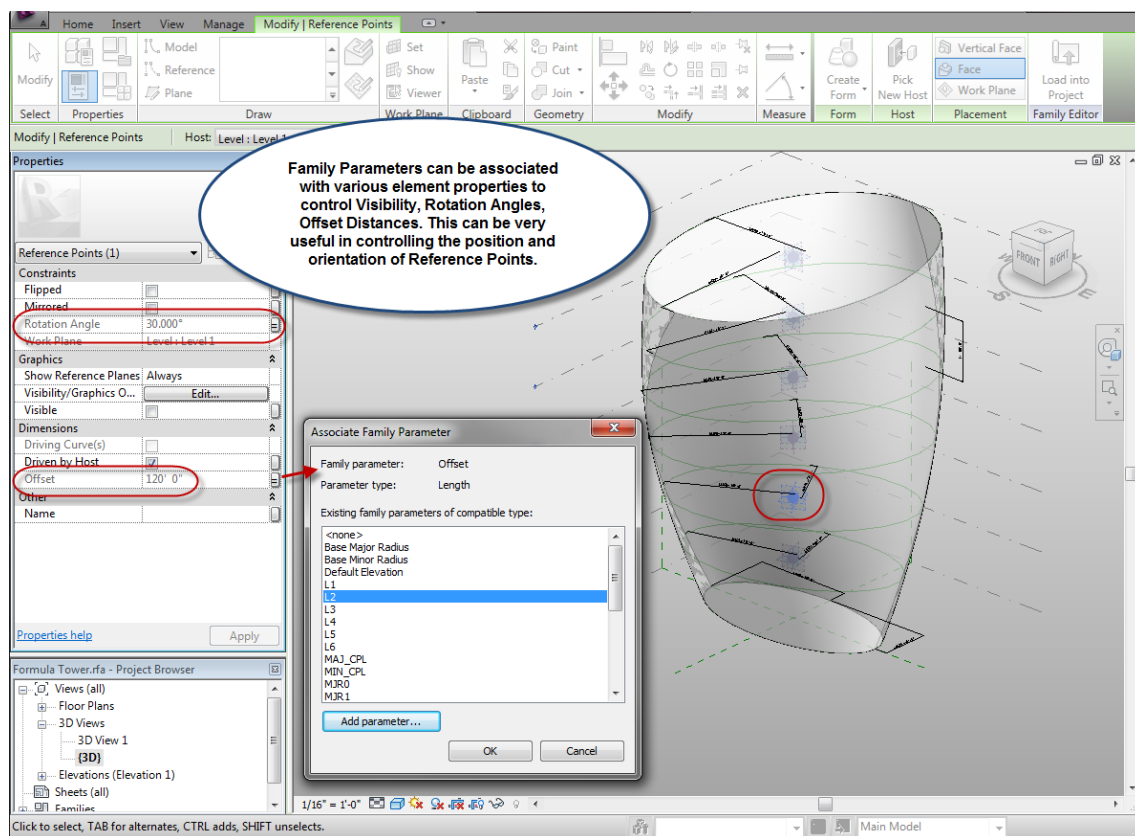
The Family Editor provides tools for creating parameters and formulas directly in the viewport as well as in the Family Types dialog. This works very similar to the methods used in creating component family parameters but you will often be working in a 3D view as well as 2D views.

Dimension parameters can be defined “on-the fly” by adding dimensions, and then choosing the Add Parameter option in the Label pulldown. If you plan your mass in advance, it can sometimes be easier to open the Family Types dialog and create the majority or even all of the dimension parameters before you start drawing any geometry.

In the Conceptual Design environment, it is possible to dynamically adjust geometry which has been parameterized with labeled dimensions. Dragging the geometry will automatically update any related parameters allowing you to easily explore design variations.

2. Working with Parameters and Formulas in Conceptual Masses

In addition to dimensional parameters defined with labeled dimensions, it is also possible to create a range of other parameters to associate with your conceptual masses. All parameters can be defined as either Instance parameters which will appear in the properties palette in the project environment or as Type parameters which will be accessed through the Edit Type properties dialog box.



These can include Visibility parameters to show different geometry options for the mass or material parameters to differentiate finishes in different areas.

Reference points include a level offset distance and a rotation angle property which can be associated with Length and Angle parameters. This allows you to control their position and rotation without adding dimensions or more reference lines. Reference points define a set of 3 reference planes which can be used to host form geometry. As you modify the point's Offset or Angle settings via parameters, the position and rotation of any hosted geometry will also be updated.

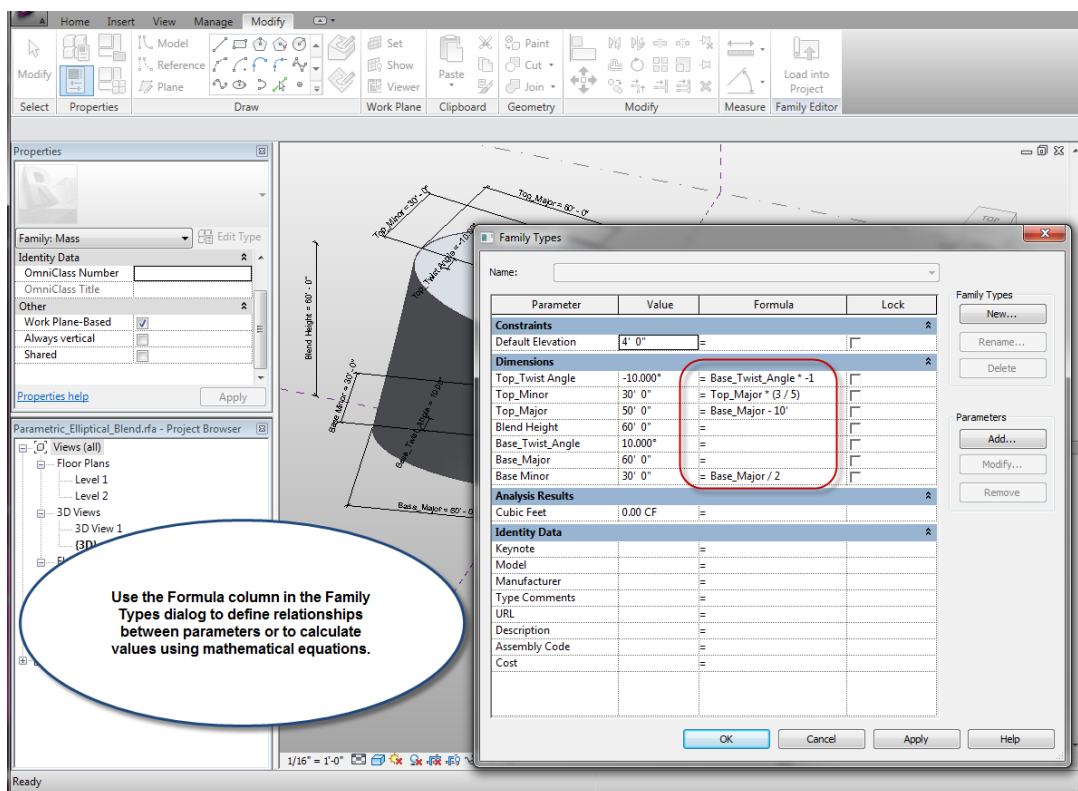
Formulas extend the capabilities of Parameters in the Family Editor by allowing you to define dependent relationships between the sizes, positions, and orientation of different elements in the mass form.

Formulas can be as simple as Distance B = Distance A * 2 or as complex as the following example which will define the shape of a Catenary arch.

$$y = a \cosh\left(\frac{x}{a}\right) = \frac{a}{2} \left(e^{x/a} + e^{-x/a}\right)$$

There are limitations on the creation and application of formulas inside Revit parameters and the equation shown above actually has to be broken down even further because Revit does not understand how to interpret the cosh value for Hyperbolic Cosin.

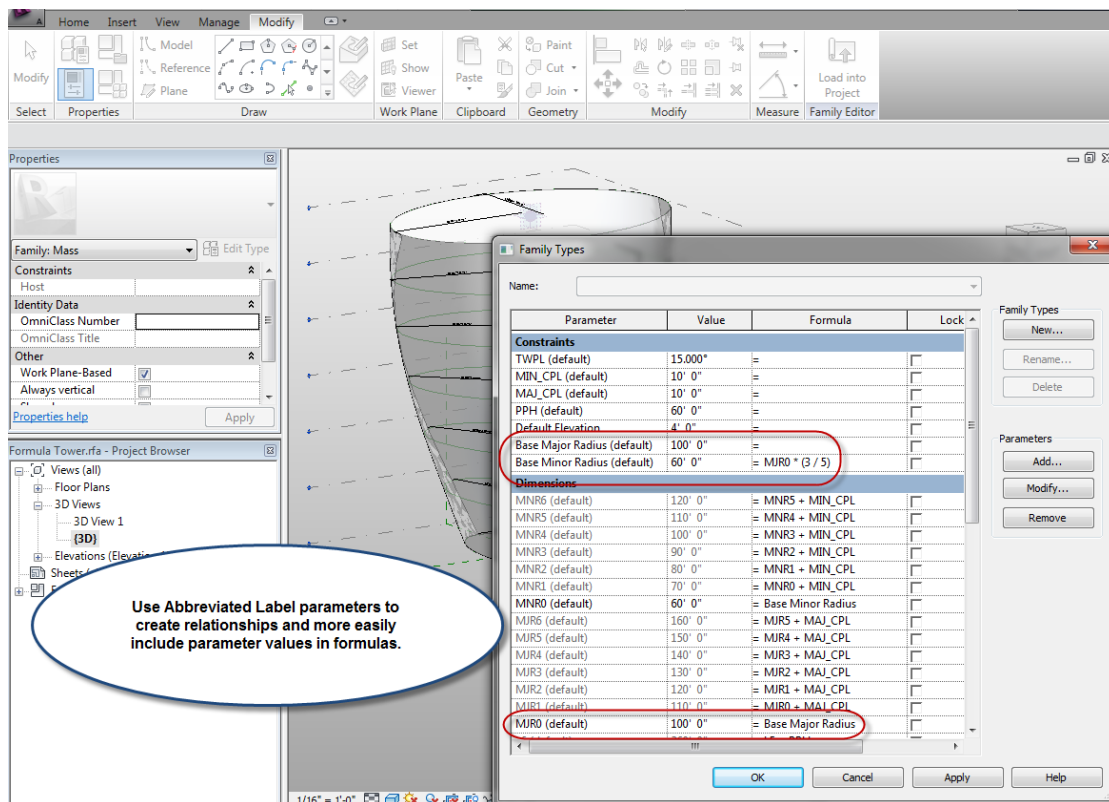
$$Y = 1m * (a/2 * (e^{(xn/a)} + e^{-(xn/a)}) - a)$$



Simple formulas are usually defined in the Dimensions or Constraints category within the Family Types dialog box.

Formulas support a wide range of arithmetic operations such as addition, subtraction, multiplication (*), division (/), exponentiation(y^x), logarithms (log), and square roots (sqrt). Revit formulas can also calculate basic trigonometric functions such as Sine, Cosine, Tangent, Arcsine, Arccosine, and Arctangent.

You can use integers, decimals, and fractional values in formulas and make use of brackets to follow normal mathematical syntax such as $\text{Width} = \text{Depth} * (\text{Height} - 3)$



When you reference other parameter names, you must follow the exact case of the original, ensuring that capitals and lowercase letters are identical. It is possible to create labeled relationships between parameters to shorten the names and make them easier to reference in formulas. For example, you could create a parameter called Base Width. You could then create a second parameter called BW which you set = to the Base Width parameter. Then, you could use the BW parameter in your formulas and know that as the value for the Base Width is modified, it will automatically be updated in all other formulas which reference the BW parameter.

Exercise Notes

- In the following exercise you will learn how to create two, parametric conceptual masses.
1. Open Revit and start a new, Conceptual mass family with the Mass.rft template. To warm up, we'll do a simple Elliptical Blend which will have parameters for its semi-major and semi-minor radius values, a height, and a twist angle.
 2. From the Draw panel, *pick Reference and then Ellipse*. Draw an ellipse with its center at the origin and its long axis along the Center Front/Back reference plane. Two temporary dimensions show the two radius values. Convert the temporary dims to permanent dimensions. If your ellipse was not created as a Reference ellipse, the tower will not respond to parameter changes.
 3. Select the longer dimension and from the label pulldown, choose Add Parameter. Create an Instance length parameter called Major Radius. (We will use all Instance parameters in the exercises today to make it faster to modify the shapes in the project environment.)
 4. Repeat for the second dimension and create a parameter called Minor Radius. In the formula column set the value to **Major Radius*.6** and then try adjusting the values to ensure the shape flexes properly.
 5. To ensure the ellipse cannot be moved from the origin, add a set of EQ dims to both sides of the shape. Zoom back a bit and type LL to create a new level. Set the height to about 50 feet.
 6. Switch to level two and draw a short reference line near the origin. Use the Align command to align and lock one end of the reference line to each of the two reference planes defining the origin. Try picking the free endpoint and dragging it a bit to change the length and rotation. Set it to about a 45 degree angle from the front/back reference plane.
 7. Add an angular dimension between the horizontal reference plane and the reference line. Label the dimension with an Instance parameter called Top Twist Angle. Try flexing the parameter to ensure the reference line rotates around the origin. Set it to 30 degrees to finish and then pick OK.

8. Switch back to your 3D view. Pick the Reference line and check its host setting to ensure it is set to Level 2. Select the ellipse on level 1 and hit CTRL-C to copy it to the clipboard. Choose the Paste pulldown on the clipboard panel and pick Paste Aligned to selected levels. Choose Level 2 and pick OK.
9. To have the top ellipse rotate with the reference line, it needs to be hosted by the reference line. Pick the ellipse and from the Host pulldown on the Options bar, choose Pick.... And then pick the reference line. Try rotating the reference line by picking it and then editing the twist angle dimension value to 45 and then 75. The ellipse follows but its rotation does not start at zero degrees. Set the rotation to 30 again.
10. Pick the ellipse and change its host to Level 2. Pick the Reference line and set its twist angle to zero degrees. Pick the ellipse again and change its host back to the reference line again. Test flex the twist angle again to see how the ellipse rotates.
11. Pick the ellipse on level two and convert its two temporary dimensions to permanent dimensions. Set the two dimensions to use the same parameters as the base ellipse. If you would like the top ellipse to vary from the bottom, you could create two more parameters for the Top Major Radius and Top Minor Radius.
12. Zoom back a bit and select the Center Front Back reference plane. Pick the dimension tool and add a vertical dimension from Level 1 to Level 2. Pick the dim and add an instance parameter called Blend Height. Try dragging the level up and down to see if the hosted elements move with it.
13. Pick the two ellipses and choose Create Form to generate a Blend. Open the family types dialog and try flexing all of the parameters to ensure the Blend responds as expected. Save the family as Twisted Blend Ellipse.
14. Start a new project and save it as Formula Complex. Switch back to the Family Editor and choose Load into Project. Place the mass family on a work plane and then switch to a 3d view. Pick the mass and view the available settings in the Properties palette. Test the family to see how it can be modified with your custom parameters. Save the file.

15. For the second part of our exercise we are going to create a complex parametric tower with numerous, inter-related parameters that will allow the mass to grow, taper, flare, or twist starting at any point along its height. Start a new conceptual family and open the Family Types dialog. Start the process by creating all of the parameters shown in the following screen shot.

Parameter	Value	Formula
Constraints		
TWPL (default)	15.000°	=
MIN_CPL (default)	10' 0"	=
MAJ_CPL (default)	10' 0"	=
PPH (default)	60' 0"	=
Default Elevation	4' 0"	=
Base Major Radius (default)	100' 0"	=
Base Minor Radius (default)	60' 0"	= MJR0 * (3 / 5)
Dimensions		
MNR6 (default)	120' 0"	= MNR5 + MIN_CPL
MNR5 (default)	110' 0"	= MNR4 + MIN_CPL
MNR4 (default)	100' 0"	= MNR3 + MIN_CPL
MNR3 (default)	90' 0"	= MNR2 + MIN_CPL
MNR2 (default)	80' 0"	= MNR1 + MIN_CPL
MNR1 (default)	70' 0"	= MNR0 + MIN_CPL
MNR0 (default)	60' 0"	= Base Minor Radius
MJR6 (default)	160' 0"	= MJR5 + MAJ_CPL
MJR5 (default)	150' 0"	= MJR4 + MAJ_CPL
MJR4 (default)	140' 0"	= MJR3 + MAJ_CPL
MJR3 (default)	130' 0"	= MJR2 + MAJ_CPL
MJR2 (default)	120' 0"	= MJR1 + MAJ_CPL
MJR1 (default)	110' 0"	= MJR0 + MAJ_CPL
MJR0 (default)	100' 0"	= Base Major Radius
L6 (default)	360' 0"	= L5 + PPH
L5 (default)	300' 0"	= L4 + PPH
L4 (default)	240' 0"	= L3 + PPH
L3 (default)	180' 0"	= L2 + PPH
L2 (default)	120' 0"	= L1 + PPH
L1 (default)	60' 0"	= PPH
A6 (default)	90.000°	= A5 + TWPL
A5 (default)	75.000°	= A4 + TWPL
A4 (default)	60.000°	= A3 + TWPL
A3 (default)	45.000°	= A2 + TWPL
A2 (default)	30.000°	= A1 + TWPL
A1 (default)	15.000°	= TWPL

16. TWPL stands for Twist Angle Per Level. MAJ_CPL = Major Radius Change Per Level. MIN_CPL = Minor Radius Change Per Level. PPH stands for Profile to Profile Height. A1 to A6 and L1 to L6 will control the angle and level offsets for the reference point at each profile level. MJR0 and MNR0 are the Major Radius and Minor Radius for each level

17. After adding all of the required parameters and formulas, create 6 new levels at 60 foot intervals.
Switch to the Level 1 view and add 6 reference points at the origin. As soon as you add the second point, a warning dialog will appear. Just pick Ok to continue.
18. Switch to a 3D view and pick one of the reference points at the origin. In the properties palette, pick the Associate parameter button beside the Offset setting under dimensions. Pick the L1 parameter. Pick another reference point and associate its offset with the L2 parameter. If L1 = PPH and PPH=60, the two reference points should now be 60 feet and 120 feet above the base level. Repeat for the remaining reference points.
19. Window select all of the reference points and in the Graphic section of the Properties palette, set the Show Reference Planes option to Always.
20. Switch to Level 1 and create a Reference ellipse centered on the Origin. Convert the ellipse's temporary dimensions to permanent dimensions. Pick the longer dimension and in the Label pulldown pick MJR0. Set the other dimension to use the MNR0 parameter. Add a set of EQ dimensions along each axis to lock the profile to the origin.
21. Pick the ellipse and hit CTRL-C to copy it to the clipboard. Use the Paste Aligned to Levels option to copy it to level 2 through level 7. Zoom in on the second ellipse up from the bottom. Pick the ellipse and convert its temporary dims to permanent dims. Set them to use the MJR1 and MNR1 parameters. The ellipse should increase in size by 10 feet in each direction as per the MJR_CPL and MNR_CPL parameter values.
22. Pick the ellipse and in the Host pulldown choose Pick. Zoom in if necessary and pick the Reference point. Select the reference point and pick the Associate Parameter button beside the Rotation Angle setting in the Constraints section of the Properties palette. The reference point and the ellipse should both rotate 15 degrees as per the TWPL parameter created and associate with the A1 parameter.
23. Open the Family types dialog and try flexing the profiles by adjusting the TWPL value. Increase it to 30 degrees, try it at -30 degrees, and then set it to 5 degrees. Smaller rotation values will keep the stack of profiles a bit neater while we associate the rest of the profiles with the reference points and the reference points with the angle parameters.
24. Pick the next ellipse up in the stack and repeat the process. Create two new dims. Associate the dims with MJR2 and MNR2 parameters. Rehost the ellipse to the reference point. Associate the reference point's rotation angle with the A2 parameter.

25. Repeat step 24 for the remaining profiles on Level 4 through Level 7. When all of the profiles have been parameterized, open the Family types dialog and flex the family.
26. Set the formula for the Base Minor Radius to be $= \text{MJR0} * .75$ and then modify the Base Major Radius value. Increase the TWPL to 15. Increase the PPH value to 100 feet. When you apply this last change, note how the profiles and reference points shift up above the levels. We only created the levels to facilitate copying the ellipses with the Paste to Aligned Levels option. The Reference points are not constrained to the upper levels but are all hosted by Level 1 and then parameterized with Level offsets associated with our L1 to L6 height parameters.
27. Close the Family Types dialog and select all 7 ellipses. Choose the Create Form tool to generate a Loft from the profiles. Open the Family types dialog and flex the family.
28. Save the family and load it into the Formula Complex project. Place the mass on a work plane and then switch to a 3D view. Pick the Mass and experiment with modifying the Constraint values in the properties palette. Try changing the MAJ_CPL and MIN_CPL values to both positive and negative values and also positive for one and negative for the other. Experiment with the TWPL to see how far you can twist the form.
29. Return to the Family Editor and use the Divide Surface tool to create a UV grid on the mass. Adjust the grid settings as desired and select a Surface pattern. Try loading this into the project and test it again.
30. Consider what other changes you could make to the Family parameters and formulas to have the twist or taper start or end at a particular level. How could you make the twist or taper accelerate or decelerate towards one end of the loft. Experiment a bit further and then save and close all files. We will continue with a discussion of 3D pattern components in the next class.